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JITAR online modules to improve math preparation of engineering students: Preliminary results

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1. Introduction

This project focuses on the enduring problem of mathematical competency of the engineering students (ES). It is based on a strongly built partnership between the Department of Mathematics and the College of Engineering at North Carolina State University to address the well-documented knowledge gap in mathematics preparation of engineering undergraduates [1, 2, 3, 4, 5, 6, 7].

From a 21st century perspective, student learning of core subjects such as mathematics and science is essential. The college level mathematics courses should provide students with an academic experience that emphasizes the use of mathematics in problem solving and modeling, should provide a foundation in quantitative literacy, and should supply the mathematics needed in partner disciplines. The report from the Mathematical Association of America (MAA) Committee on the Undergraduate Program in Mathematics (CUPM) emphasizes the need to prepare students majoring in partner disciplines, including engineering, with a major recommendation to promote interdisciplinary collaboration. This recommendation was heavily influenced by the findings of the MAA Curriculum Foundations project, whose report is published in *The Curriculum Foundations Project: Voices of the Partner Disciplines* [8]. The mathematics knowledge and skills gap encountered by undergraduate engineering students when they enter the engineering courses requiring the use of mathematics abilities, taught in the three semester calculus sequence and Differential Equations courses, has been well documented [1, 4, 9, 10, 5, 6]. However, there is 'widespread agreement among academics and practicing engineers that a good grounding in mathematics is essential for engineers' [11, 12].

Online computer-aided assessment and learning packages have been shown to be an effective tool for increasing engineering students' knowledge of experimental design [13, 14], with students with access to interactive online materials scoring significantly higher on tests than students in control groups without access to such materials [15, 16, 14]. A similar effect has been seen in mathematics classes, where students who completed web-based homework assignments performed significantly higher on final exams than did control groups [16, 17]. Furthermore, there is recent research about e-learning, studying whether the adaptive e-learning content delivered can help improve student performance. The results obtained confirm that students who receive learning content that was tailor-made to their background learn more than their peers who received material which was mismatched to their background [18, 19].

Exploring this approach, the Australia Mathematical Sciences Institute made recommendations for improving the mathematics education for engineering students using on-line tools and resources. This included the development of an on-line formative assessment with an item bank of formative test questions, automatic grading and feedback, so that compulsory online quizzes could be conducted during the semester for large engineering mathematics classes [11]. Similarly, **H**elping **E**ngineers **L**earn **M**athematics (HELM), a curriculum development project undertaken by a consortium of five English universities uses computer aided assessments

(CAA) to encourage formative self-assessment by students, so they can verify that the appropriate skills have been learned in their mathematics classes [20, 21]. Students can take a formative test multiple times to review material prior to completing a summative test, the latter score counting as coursework. In both these projects, the focus is on using computer-aided processes to support student learning of mathematics in mathematics classes, rather than in engineering courses.

The main focus of the project is directly on improving and enhancing student learning of mathematics in engineering and the application of knowledge and skills in the context of engineering courses. The team’s approach was to design an instructional tool to offer assessment and e-learning assistance to students through customized learning paths. The instructional tool is delivered through an intuitive software interface designed to integrate these key components, assessment and e-learning assistance. The e-instruction focused on improvement of ES’ mathematical abilities in the context of a selected number of engineering courses, and in particular to provide a series of <u>J</u>ust-<u>i</u>n-<u>T</u>ime <u>A</u>ssessment and <u>R</u>eview (JITAR) modules to be interspersed into engineering course content, as needed to meet ES’ mathematical pre-requisite skills needed to succeed in the upcoming engineering content. The main idea is to set up an automated engine that meets the student at his/her current level of mathematical ability, help him/her identify the stumbling blocks, and offer instructional guidance to learn concepts and skills. Additionally, we contend that the sequence of online instructional activities provides ES with the opportunity to bridge the mathematical content to specific engineering contexts, thus addressing a continuous need in engineering education to integrate mathematics with applications in specific engineering disciplines.

No literature was found on the impact of online modules in enhancing student’s knowledge of mathematics in the context of engineering courses. Our hypothesis is that online assessment, review of mathematics topics, and, most importantly, the practice of essential mathematical skills in the context of engineering courses, will assist students in reaching the mathematical mastery needed to be successful in their engineering courses in particular and in their chosen engineering field in general.

2. The problem

The mathematical education of the engineering undergraduates essentially consists of the students assimilating a large collection of 'methods' and 'techniques' that later on in their education and profession should enable them to understand and solve advanced engineering problems. Evidence resulting from the continuous assessment process performed by the mathematics department at our university shows that by the end of a given semester, the majority of engineering students have mastered core concepts outlined by the math course outcomes. However, as seen in the literature reviewed and articulated by many engineering faculty at our university, engineering educators consistently deal with a two-fold 'mathematics problem'.

On one hand, we are dealing with the fact that students easily forget material from one year to another, and often times they do not recognize the extent of what they have forgotten and even when they do recall the overall concepts, they tend to have forgotten finer details. This is further complicated by the fact that not all students continue with their required engineering courses immediately after they completed their mathematics pre-requisite courses, so their focus tends to be on the immediate assessment, not on what might be required in the future - "If it doesn't count, it is not done"!

On the other hand, students often do not clearly understand, at the time they are taught, how the mathematics relates to their chosen field of study in engineering. Several examples have been collected to specifically demonstrate this mathematical knowledge gap in programs within the College of Engineering [5]. A similar study was done during Summer 2002 through Spring 2004 within the College of Engineering and Applied Science at the University of Wisconsin-Milwaukee [9] where the author looked at the grades of recent graduates as a function of their mathematical background. The relative success of students as a function of their initial math placement, their course sequence, their student status (full-time or part-time), and the institution taken were studied. These results were in line with the our earlier findings [5].

3. The proposed solution

In this section we present an overview of the proposed solution to this broad problem encountered across engineering disciplines. An important aspect of the work is the integration of the relevant mathematical content into specific applied engineering contexts in an effort to improve ES' understanding of the relationship between mathematics and their field of study in engineering. Since each engineering topic requires different mathematical concepts at different times in the learning curve, one of the first decisions from our group in the conceptualization of the learning materials, was to spread the relevant mathematical content over a semester in such a way that students have a chance to review content just as they are needed in the engineering course. Our goal in this project is to develop, try out, evaluate, analyze, and refine a set of e-learning and assessment resources structured in at least six online mathematics modules, to be used in at least four engineering courses, to address the ES' need to improve their mathematics knowledge and skills, at the appropriate time they need it.

The Just-in-Time Teaching (JiTT) strategy was first developed by Novak in the 1960s [22]. The essential element of JiTT involves students doing short preparatory assignments that are due before class starts. The instructor reviews the student responses before the start of class and is able to "engage the students at their level of background knowledge and use their answers as input for class discussion". Novak showed that students engaged in JiTTs performed better than students not using the strategy. Today, the JiTT strategy is widely used in academia and in many cases it is web-based, where "active learner assignments and enrichment materials are delivered to the students over the web" [23, 24, 25]. New interactive technologies, used together with the JiTT approach have the potential to increase student's knowledge because (a) the learners are actively engaged, (b) the material is delivered at the point in time that students need the knowledge, and (c) they receive prompt feedback about their learning, such that they are able to refine their conceptual understanding [26]. Thus, developing a set of mathematics materials, to be delivered to students in an online environment at the time they need to review or re-learn mathematical concepts and skills, is a reasonable solution to the problem identified earlier. Specifically, the main student learning objectives of this project are that students will:

- master core mathematical skills;
- identify how the mathematical concepts/skills relate to the engineering context;
- develop creativity in defining problems, seeking solutions, and interpreting the mathematical results in the applied context;

With the cooperation of engineering faculty teaching four different engineering courses, key mathematical concepts and skills needed in those courses have been identified. We are developing a series of Just-In-Time Assessment and Review (JITAR) mathematics modules for each of the four courses, for JIT-focused delivery to students using an online e-learning mechanism. These modules are being designed specifically to assess the entry level on essential mathematical knowledge and skills, to provide students with personalized review and practice materials, conduct post-tests based on pre-test results, and to integrate the mathematics with specific engineering applications. If students have a chance to review and incorporate the necessary mathematics in their engineering classes before they are introduced to more complex topics, they will gain a greater appreciation of the power of mathematics in their field and increase their confidence and enthusiasm for using mathematics in the process of learning new engineering concepts.

This approach for JITAR module delivery is consistent with the constructivist approach of starting with a student's pre-existing knowledge and building concepts from that point, through assimilation (adding new knowledge to an existing schema) or by accommodation (changing an existing schema or conceptual structure, i.e., through conceptual change) [27, 24]. Through the envisioned process where specific material is presented to address a particular conceptual or skill weakness, a student's knowledge is scaffolded, enabling them to perform cognitively demanding tasks that were previously beyond their ability [28, 29]. A simple quiz, or having students reviewing text material on their own, would be less effective because those processes would not target the specific problem areas and would not scaffold learning. Thus, the proposed process is based on sound pedagogical theories and practices.

In order to encourage students to complete the JITAR modules (JITARs), these JITARs are considered coursework and a homework grade, done as preparation for the learning of new engineering topics. By conducting this kind of ongoing formative assessment and review activities (JITARs), students should have a higher improved median level of math competency allowing them to easily connect new knowledge to old. Also, engineering faculty should be able to determine when mid-course adjustments are warranted and should have more instructional time for the new engineering topics. Faculty should be able to introduce the new engineering concepts in a more sophisticated and meaningful manner. Finally, this modular approach allows students to break up their work in manageable chunks so they can structure their time and their ways of reviewing the necessary mathematical concepts, which otherwise could be overwhelming.

4. JITAR Design

Problems in the JITARs address different levels of mathematical ability, from basic mathematical knowledge and skills, to more advanced problems. Questions range from routine to demanding. Many questions have intermediate step answers to provide partial credit. Some problems require specially formatted answers so that the solution processes can be evaluated. Some problems walk students through small step-by-step arguments and expose them to engineering terminology and notation, possibly different from the ones they previously were exposed to, in an active fashion. Further, the engineering faculty provide ‘thought-provoking’ questions for connecting the mathematical concepts to engineering contexts, ensuring that questions are testing the student’s ability to understand the ‘meaning of the symbols’ in mathematics and not only the mathematical syntax [30].

The team decided to work with WeBWorK as their on-line delivery software. WeBWorK [31, 32] is the largest free, open source homework system for instructors and students and is in use in over 500 colleges and high schools. It supports questions and notation typically found in mathematics and other scientific textbooks as well as more advanced interactive questions, thus surpassing other on-line homework systems whose flexibility in checking answers to questions is more limited. WeBWorK syntax is very similar to calculator syntax, so the students should not encounter any difficulty entering symbolic answers. In addition to multiple-choice responses, this system can grade free response numerical answers, free response answers involving mathematical expressions, and, in fact, any type of answer for which it is possible to write programmed instructions to determine correctness. Each student receives individualized problems; gets immediate feedback about the validity of his or her answers, enabling the student to correct mistakes while still thinking about the problem; and is encouraged to continue reworking the problem until he or she gets the correct answer.

The key instructional design ideas identified by the team were incorporated into a new type of WeBWorK assignment JITAR in which content of the homework set changes depending on student performance. Initially, the student is shown a collection of questions. However, each problem can (but does not have to) have a collection of associated child problems. If a student gets a question wrong (and runs out of attempts) or passes a certain threshold of incorrect attempts (set by the instructor), then the child problems will be presented to the student. The student has to complete the child problems, which are meant to contain review and practice for the concept presented in the parent problem. The student’s grades on the child problems can count towards the parent problem, but they don't have to. The child problems can have their own child problems, if additional review is needed on a particular subtopic. After completing the child problems, the student can proceed to the next parent problem from the original collection. If they are unable to complete the child problems then there is an option for the instructor to be notified. For example, this set may have the following problem structure.

Main Problem 1: Asks if students can give the exponential representation of a complex number

- (a) Child Problem 1: Complex Number Review (video)
- (b) Child Problem 2: Converting a complex number to exponential form walkthrough (multi-step scaffolded problem)
- (c) Child Problem 3: Practice conversion problem
- (d) Child Problem 4: Re evaluate if a student can give the exponential representation of a complex number.

An example of a (partial) JITAR assignment is presented in Figure 1 below. One can see from the attempts that the student navigated through the JITAR assignment according to his/her abilities. Problem 1 could not be answered initially, so the student was directed to complete problems 1.1 and 1.2 containing review material related to problem 1. Since these child problems were answered correctly, there was no need to attempt the problem child 1.1.1. On the other hand, problem 2 was solved correctly in one attempt so the system didn't open problem child 2.1. Similar flow can be visible on problem 3 and its sub-problems.

Figure 1 shows the structure and the flow of the systematized assessment and review process.

Name	Attempts	Remaining	Worth	Adjusted Status
Problem 1	4	1	1	100%
Problem 1.1	1	4		
Problem 1.1.1	0	5		
Problem 1.2	1	4		
Problem 2	1	4	1	100%
Problem 2.1	0	5	1	
Problem 3	8	7	1	100%
Problem 3.1	3	2	1	
Problem 3.2	5	0	1	
Problem 3.3	1	4	1	
Problem 3.4	5	0	1	

Figure 1: Sample of a JITAR set completed by a student

Figure 2 below shows an example of a child problem with an embedded YouTube video for review purposes.

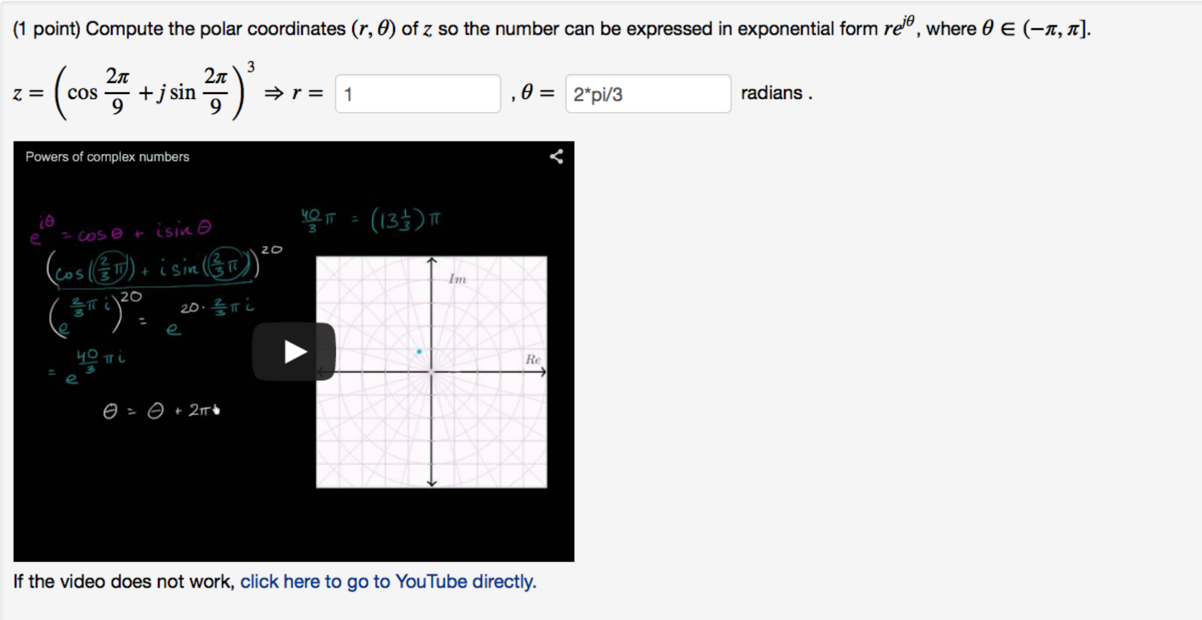

Figure 2: Sample of a JITAR question and review material

Because of the design of the JITAR software, the instructor is able to monitor each student's pathway through the material and keep track of his or her scores. We will be able to research areas with which students have particular problems and monitor how the JITAR modules enhance students' learning of such difficult topics.

5. Implementation

Faculty members from eight engineering programs were surveyed in 2009 to establish the specific mathematics areas that students need proficiency in order to succeed in their engineering courses. The first JITARs being developed address the most common mathematical needs across engineering disciplines. These mathematics topics are in line with the findings of the reports on the engineering workshops of *The Curriculum Foundations Project: Voices of the Partner Disciplines* [8]. The selection also takes into account the opinions from both mathematicians and engineering educators, that these are the concepts that have the potential to strengthen ES' understanding of advanced mathematics, conceptualization of the STEM disciplines, and gaining a profound understanding of fundamental engineering mathematics [1, 8, 6, 11]. Broad topics needing JITARs are presented in the matrix below.

Table 1: Topics planned for initial JITAR development

Course	Linear Systems In BME	Intro. To Systems, Signals, Circuits.	Analytical Foundations Of ECE	Engineering Mechanics – Statics (CE)
Approximate student numbers	≈ 55 p.a.	≈ 160 p.a.	≈ 120 p.a.	≈ 300 p.a.
Topic				
1. Basic algebra and trigonometry	✓	✓	✓	✓
2. Representations of complex numbers	✓		✓	
3. Exponentials and logarithms	✓	✓	✓	
4. Graphical analysis of functions	✓	✓	✓	✓
5. Differentiation and applications			✓	
6. Integration techniques, including partial fractions, integration by parts, substitution	✓		✓	
7. Applications of Integrals: areas, volumes, centroids, moments				✓
8. First and second order ordinary differential equations			✓	
9. Laplace transform	✓		✓	
10. Vector operations				✓
11. Linear systems and determinants	✓		✓	

Each of these broad topics will include several JITAR modules. Each module will consist of mixed concepts extracted from the mathematical areas noted above. We will start by developing the JITARs for concepts and skills common to all four courses. Participating engineering faculty will write related engineering questions and provide relevant engineering resource materials. After the selection of the topics, the learning materials are embedded into the interactive online e-learning system, structuring it in a similar way for each of the modules.

We piloted this project in the fall of 2009 in a 300-level Linear Systems for Biomedical Engineers course, implementing a paper and pencil test, with online review material in .pdf form, and followed by a post-assessment of students. Initial results showed that having students review relevant mathematical concepts and procedures helped them to improve their mathematical competence and confidence, thus increasing their chances for success in the engineering course, as indicated by the improved score on a common final exam question [33]. However, our approach was 'primitive' in that we used paper-and-pencil tests, and the review material was provided as non-interactive PDF files and we had no way of determining whether or not students completed any of the suggested practice items. Furthermore, 1) the review materials were not customized to each learner based on their results on the pre-test and all students got the same review materials; and 2) the review materials were given to students after the test was completed rather than during it. With the personalized, interactive JITAR modules, we hypothesize that student learning of mathematical content for engineering will be even more significant.

The implementation of the JITAR WeBWorK modules started with the same 300-level Linear Systems course in fall 2014 with 61 students. This is a typical Electrical Engineering based Linear Systems course with applications chosen from the discipline of Biomedical Engineering. Below is the list of possible mathematics topics, and engineering areas of applicability, for the JITAR module.

Table 2: Mathematics topics and engineering areas of applicability for the JITAR module.

JITAR Module 1	Engineering contexts
Representation of complex numbers Complex arithmetic Complex functions Complex integrals	Laplace Transforms Z-transforms The Fourier Series The Fourier Transforms Sampling of Signals The Discrete Time Fourier Series The Discrete Time Fourier Transforms

As the student moves through the module, the questions increase in difficulty, starting with basic mathematical ones and ending with questions from the engineering context. Each student has a different version of each problem. The questions may require numerical or symbolic answers, or they are in multiple choice format. The module has a total of 45 problems, 14 of which are parent problems, 23 are child problems and 8 grandchild problems.

The first seven parent problems are on representation of complex numbers and complex arithmetic. We start with simple addition of two complex numbers in rectangular form, continue with division and multiplication. Next we do the same operations with exponential representation of complex numbers and practice the conversion between the forms. Finally, we focus on finding the roots of the complex numbers. In the next seven parent problems, we cover complex functions of real variable, complex functions of integer variable, differentiation and integration of complex functions and graphing complex functions.

The learning materials used in child problems are presented in various formats (text files, videos, Mediasite, websites, etc.) and cover the mathematics theory in a form that is easy to understand, with worked examples, including engineering applications.

6. Results

When we piloted this project in the fall of 2009 our results showed positive improvement for students when they had access to review materials, compared to those in a previous semester without review materials[33]. We continued to gather data over multiple years and based on these results, we applied for and obtained a NSF grant to further the work. This section reports on the results from fall 2014, after the use of online JITAR modules in WeBWorK.

6.1. 2013 and 2014 comparisons

Students in the 2013 and 2014 sections of the course were compared on a number of different variables. The 2013 students had a higher overall entering GPA (mean = 3.61) than the 2014 students (mean = 3.52) although the difference was not statistically significant (t = 1.427, p = 0.073).

6.1.1. Pre-test

In addition to basic differential and integral calculus, students entering a 300-level Biomedical Engineering class are expected to know how to solve first and second order differential equations, how to manipulate and graph functions, and how to work with complex numbers. On the first day of class, students in both years were given a diagnostic pre-test covering the essential math skills and concepts needed for the course. The test focused on piecewise functions, graphing sinusoidal signals, complex algebra, and evaluating improper integrals. Each question was worth 3 points. Results are presented in the table 3 below.

Table 3: Pre-test results for the 2013 and 2014 sections of the course

2013 Pre Test Data (N=58)	**Mean Score**	**2014** Pre Test Data (N=61)	**Mean Score**
Q1: 78.7% (graphing sinusoids)	2.36	Q1: 76% (graphing sinusoids)	2.25
Q2: 43.6% (graphing step function)	1.31	Q2: 38% (graphing step function)	1.15
Q3: 66.6% (complex arithmetic)	2.00	Q3: 59% (complex arithmetic)	1.79
Q4: 7.5% (indefinite integrals)	.224	Q4: 7% (indefinite integrals)	.213
Avg: 49.1%	5.90	Avg: 45%	5.39

While the students in the 2013 course performed better on the pre-test, the difference was not statistically significant for any of the questions, nor the total score.

6.1.2. Comparisons of tests, problems and exams

Similar tests and exams were used in 2013 and 2014. The 2014 students performed slightly worse at the beginning of the semester than did the 2013 students, but had made gains by the end of the year, although there were no significant differences between years on the final exam and final grade (see table below). Also students in 2014 performed better on the second test (after the JITAR module) than the 2013 students, although the difference was not statistically significant.

Table 4: Comparison of 2013 and 2014 results on tests, problems and exams

	Group Statistics								
	Year	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed)**	
Test 1	2013	58	86.50	10.306	1.353	.566	117	.573	Equal variances assumed
	2014	61	85.62	6.208	.795	.559	92.638	.578	Equal variances not assumed
Test 2	2013	58	86.79	9.767	1.282	-1.190	117	.237	Equal variances assumed
	2014	61	88.80	8.656	1.108	-1.186	113.690	.238	Equal variances not assumed
Problem 1	2013	58	17.53	3.240	.425	-2.638	117	.009	Equal variances assumed
	2014	61	18.75	1.556	.199	-2.596	81.042	.011	Equal variances not assumed
Final exam	2013	58	79.79	13.871	1.821	1.830	117	.070	Equal variances assumed
	2014	61	75.77	9.861	1.263	1.815	102.466	.072	Equal variances not assumed
Final grade	2013	58	84.01	10.73	1.41	-.858	117	.393	Equal variances assumed
	2014	61	85.4	6.61	.85	-.848	93.940	.398	Equal variances not assumed

Problem 1 (on the final exam) relates directly to the JITAR module that was completed. Results show that students in 2014 scored significantly higher on that item than those in 2013 (t = -2.638, p<0.01). These results suggest that the JITAR module successfully increase student's knowledge and ability to answer the problem.

6.1.3. Male and female students

In 2013, no significant differences between male and female students were observed on any assignments.

In 2014, female students had significantly lower scores (M =83.6, SD = 6.64) on test 1 than male students (M =87.1, SD = 5.54, t = 2.234, p<0.05). By the end of the semester, there were no overall significant differences between male and female students, although their overall scores were lower on all assignments, excepting problem 1. Female students (M =18.68, SD = 1.46) did as well as the male students (M =18.81, SD = 1.64) on problem 1, which relates to the JITAR module. This result suggests that female students benefited from the JITAR intervention and this will be further explored in subsequent iterations of implementation.

6.1.4. Grade distribution

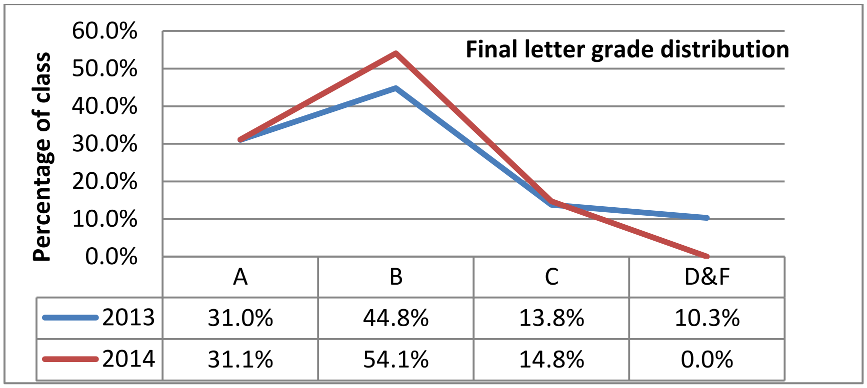

Figure 3: Distribution of letter grades in 2014 and 2014

The distribution of course grades across both years were similar, excepting that more students obtained a B grade and no students obtained Ds or F grades in 2014. This result was achieved despite the 2014 group having an average lower entering GPA. This suggests that the JITAR module motivated students to persist in their coursework, resulting in an improvement in the average grade.

6.2. WeBWorK module scores

All students completed the JITAR module. The final paper will provide data showing scores on individual problems as well as persistence. **Survey results**

Students completed a survey after completing the JITAR module. The survey contained Likert Scale questions, as well as six open response questions
(1) Which of the review materials were the most useful to you?
(2) Which of the review materials were least helpful?
(3) What did you like the most about the WeBWorK module?
(4) What did you like the least about the WeBWorK module?
(5)What changes would you like to see regarding the structure (flow) of the module?
(6) What other suggestions do you have for improving the WeBWorK module?
The open-ended responses are still being coded in detail for common themes and the full results will be presented in the final paper. Results of the Likert scale questions are presented below.

Table 5: Post-JITAR module survey results

#	Question	Strongly agree	Agree	Disagree	Strongly Disagree	N	Mean
1	The module was easy to navigate from one problem to the next.	31.9%	51.1%	12.8%	4.3%	47	3.1
2	The answer preview was helpful.	53.2%	42.6%	4.3%	0.0%	47	3.5
3	The questions were at an appropriate level of difficulty.	10.6%	55.3%	31.9%	2.1%	47	2.7
4	Having easier problems to work through first was helpful to my learning.	37.8%	55.6%	6.7%	0.0%	45	3.3
5	The number of problems to work through was appropriate.	8.5%	72.3%	19.1%	0.0%	47	2.9
6	The length of time it took me to complete the module was appropriate to the concepts covered.	8.5%	46.8%	38.3%	6.4%	47	2.6
7	The additional review material was helpful to my learning.	22.2%	71.1%	6.7%	0.0%	45	3.2
8	There was sufficient review material to help me when I needed assistance.	8.9%	55.6%	24.4%	11.1%	45	2.6
9	The text material in the module was helpful to my learning.	5.1%	53.8%	35.9%	5.1%	39	2.6
10	The video material was helpful to my learning.	17.1%	54.3%	28.6%	0.0%	35	2.9
11	At the end of the module, I felt much more familiar with the material than when I started.	23.4%	68.1%	8.5%	0.0%	47	3.1
12	I was satisfied with the scores I received.	31.9%	63.8%	4.3%	0.0%	47	3.3
13	Completing the WeBWork module helped me with completing the next homework assignment on Laplace Transforms	17.4%	67.4%	10.9%	4.3%	46	3.0

Ninety-three point three percent of students agreed or strongly agreed that the review was helpful to their learning; and 91.5% felt more familiar with the material after completing the JITAR. For the next survey, students who disagreed with these statements will be prompted to explain their responses. Questions numbered 3, 5 and 7 were ambiguous and will be rephrased for the spring 2015 class. The majority of students commented that they liked the instant feedback provided by JITAR, when asked what they like most about the WeBWorK.

In addition, the researchers read all the open-ended responses and have made adjustments to the system based on the student input. For instance, students complained they did not like working sequentially through all the problems because the JITAR system was set up so that they could not proceed to the next question before completing the one before. For the spring 2015 class, this feature will be turned off, so students can answer questions in any order, but they will be prompted that it would be better to answer them sequentially because the questions build upon each other in complexity as the student progresses through the JITAR. We will monitor if this makes a difference to their attitudes to the flow of the JITAR.

Some students also found the flow of the JITAR a little confusing, so the research team is planning to develop a short Camtasia video that will guide students through the flow of a typical JITAR. Students also tended to be of the mindset that they did not want to fail any question, rather than seeing the system as a learning tool for improvement. The video will address these issues and will be embedded at the beginning of each JITAR.

7. Conclusions

In this paper, we presented the preliminary results from the implementation of first JITAR module on Complex Numbers and Complex Functions. The results are promising and we received valuable feedback from students to improve the design of the modules. We will continue designing more modules and testing them in a variety of courses.

8. Bibliography

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